

bending angle of the toe in a bendable range of the toe” to --- to be bendable with respect to the foot main body, and a bending angle holder capable of holding a bending angle of the toe in a bendable range of the toe from zero degree at which a contact area of the foot becomes maximum to a predetermined degree, the bending angle holder holding the toe at the bending angle comprising one from among the zero degree, the predetermined degree and an arbitrary angle between the zero degree and the predetermined angle---. (As underlined)

(2) Amended in Specification P. 5 (paragraph 0025), L. 20-22, “a bending angle holder capable of holding a bending angle of the toe in a bendable range of the toe” to --- a bending angle holder capable of holding a bending angle of the toe in a bendable range of the toe from zero degree at which a contact area of the foot becomes maximum to a predetermined degree, the bending angle holder holding the toe at the bending angle comprising one from among the zero degree, the predetermined degree and an arbitrary angle between the zero degree and the predetermined angle---. (As underlined)

(3) Amended in Specification P. 44 (paragraph 0228), L. 11, “a bending angle (θ_t) of the toe in a bendable range of the toe” to --- a bending angle (θ_t) of the toe in a bendable range of the toe from zero degree at which a contact area of the foot becomes maximum to a predetermined degree, the bending angle holder holding the toe at the bending angle (θ_t) comprising one from among the zero degree, the predetermined degree and an arbitrary angle between the zero degree and the predetermined angle---. (As underlined)

(4) Amended in Claim 1, “a bending angle of the toe in a bendable range of the toe” to ---a bending angle of the toe in a bendable range of the toe from zero degree at which a contact area of the foot becomes maximum to a predetermined degree, the bending angle holder holding the toe at the bending angle comprising one from among the zero degree, the predetermined degree and an arbitrary angle between the zero degree and the predetermined angle---. (As underlined)

6. PAPERS ATTACHED HERETO

Specification A replaced paper of P. 2, 2/1, 5, 5/1, 44, 44/1. 1

Claim A replaced paper of P. 49, 49/1.

1

(Note: the numbers of page and line in Specification are expressed in accordance with the English text.)

[0004] Moreover, when a long tiptoe standing period occurs at the late stage of the supporting leg, such as during stair climbing, a problem arises in that stable posture control is difficult to achieve if the toe is in the free state.

[0005] Therefore, the object of this invention lies in overcoming the aforesaid
5 problems and in providing a legged mobile robot and a control system thereof which prevents posture destabilization by the toes contacting the floor immediately after liftoff and improves stability during tiptoe standing.

Means for solving the problems

10 [0006] In order to achieve the object, as recited in claim 1 mentioned below, this invention is configured to have a legged mobile robot having a body and legs whose upper ends are connected to the body and whose lower ends are each connected to a foot to be movable when the legs are driven, characterized in that the foot comprises a foot
15 main body connected to each of the legs, a toe provided at a fore end of the foot main body to be bendable with respect to the foot main body, and a bending angle holder capable of holding a bending angle of the toe in a bendable range of the toe from zero degree at which a contact area of the foot becomes maximum to a predetermined degree, the bending angle holder holding the toe at the bending angle comprising one from
20 among the zero degree, the predetermined degree and an arbitrary angle between the zero degree and the predetermined angle.

[0007] Further, as recited in claim 2 mentioned below, this invention is configured to further include a bending angle change suppressor that suppresses change of the bending angle of the toe.

[0008] Further, as recited in claim 3 mentioned below, this invention is configured
25 such that the toe is made continuous with the foot main body and is made of an elastic material that bends with flexing.

[0009] Further, as recited in claim 4 mentioned below, this invention is configured such that the toe is connected to the fore end of the foot main body through a rotational shaft capable of rotating about a pitch axis.

[0010] Further, as recited in claim 5 mentioned below, this invention is configured to further include an urging means for urging the toe in a direction of restoring it to an initial position.

[0011] Further, as recited in claim 6 mentioned below, this invention is configured

to further include a bending angle change suppressor that suppresses change of the bending angle of the toe in accordance with a predetermined resistance characteristic set with respect to angular velocity of the bending angle, and the bending angle controlling means manipulates a position or posture of the foot from the fourth time point to the first time point at the next time to regulate the bending angular velocity of the toe, thereby varying magnitude of resistance produced by the bending angle change suppressor to control a floor reaction force acting to the robot through the foot.

[0024] Further, as recited in claim 19 mentioned below, this invention is configured to further include a bending angle change suppressor that suppresses change of the bending angle of the toe; a bending angle detecting means for detecting the bending angle of the toe, and a floor shape estimating means for estimating shape of the floor on which the foot is based on at least the detected bending angle, and the bending angle controlling means operates the bending angle change suppressor from the fourth time point to the first time point at the next time based on at least the estimated shape of the floor to control a floor reaction force acting to the robot through the foot.

Effects of the invention

[0025] Since the legged mobile robot recited in claim 1 is configured such that the foot comprises a foot main body connected to each of the legs, a toe provided at a fore end of the foot main body to be bendable with respect to the foot main body, and a bending angle holder capable of holding a bending angle of the toe in a bendable range of the toe from zero degree at which a contact area of the foot becomes maximum to a predetermined degree, the bending angle holder holding the toe at the bending angle comprising one from among the zero degree, the predetermined degree and an arbitrary angle between the zero degree and the predetermined angle, the bending angle at the time of liftoff can continue to be held after liftoff, whereby the robot can be prevented from becoming unstable owing to the toe contacting the floor immediately after liftoff. In addition, stability during tiptoe standing can be enhanced owing to the fact that the bending angle of the toe can be held (the toe can be locked) also during tiptoe standing.

[0026] Further, since the legged mobile robot recited in claim 2 is configured to further include a bending angle change suppressor that suppresses change of the bending angle of the toe, in addition to the effects mentioned above, occurrence of

is incorporated in the foot compensating angle determiner explained in the sixth embodiment, it is also acceptable to incorporate it in the foot compensating angle determiners explained in the other embodiments.

[0228] In the first to ninth embodiments of this invention are configured to have a
5 legged mobile robot (1) having a body (24) and legs (2R, 2L) whose upper ends are
connected to the body and whose lower ends are each connected to a foot (22, 222, 223,
224) to be movable when the legs are driven, characterized in that the foot comprises a
foot main body (22m, 222m, 223m, 224m) connected to each of the legs, a toe (22t,
222t, 223t, 224t) provided at a fore end of the foot main body to be bendable with
10 respect to the foot main body, and a bending angle holder (damper 50, friction brake 60)
capable of holding a bending angle (θ_t) of the toe in a bendable range of the toe from
zero degree at which a contact area of the foot becomes maximum to a predetermined
degree, the bending angle holder holding the toe at the bending angle (θ_t) comprising
one from among the zero degree, the predetermined degree and an arbitrary angle
15 between the zero degree and the predetermined angle.

[0229] Further, they are configured to further include a bending angle change
suppressor (damper 50, damper 500, friction brake 60) that suppresses change of the
bending angle of the toe.

[0230] Further, the first embodiment and the third to ninth embodiments are
20 configured such that the toe (22t, 223t, 224t) is made continuous with the foot main
body (22m, 223m, 224m) and is made of an elastic material that bends with flexing.

[0231] Further, the second to ninth embodiments are configured such that the toe
(222t, 223t, 224t) is connected to the fore end of the foot main body through a rotational
shaft (222a) capable of rotating about a pitch axis.

25 [0232] Further, the second to ninth embodiments are configured to further include
an urging means (restoring spring 222b) for urging the toe in a direction of restoring it
to an initial position.

[0233] Further, the third to sixth embodiments are configured such that the
bending angle holder comprises a friction brake (60).

[0234] Further, the first, second, third, fifth, seventh, eighth and ninth embodiments are configured such that the bending angle change suppressor comprises a damper (50, 500).

[0235] Further, the fourth, sixth and ninth embodiments are configured such that